Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of:	)	
	)	
Authorizing Permissive Use of the “Next Generation” Broadcast Television Standard	)	GN Docket No. 16-142
	)	
	)	

<u>Comments of</u>

Rolando Bettancourt, Ph.D. Candidate
Marvin A Sirbu, Professor

Department of Engineering & Public Policy,
Carnegie Mellon University[1]
5000 Forbes Avenue
Pittsburgh, PA 15213
rbettancourt@cmu.edu
sirbu@cmu.edu

May 9, 2017

[1] Disclaimer: The institutional affiliation is for identification purposes only. The following views are those of the authors and do not necessarily represent the views of Carnegie Mellon University or its Department of Engineering and Public Policy

SUMMARY

The authors submit these comments in response to the Commission's *Notice of Proposed Rulemaking* ("NPRM") concerning the authorization of television broadcasters to use the "Next Generation" broadcast television (Next Gen TV) transmission standard ATSC 3.0. We attach to this comment the study called *Quantifying LDM Mobile TV Service Coverage Spillover into Fixed Rooftop Reception: Increased Coverage Overlap Between U.S. Service Areas*. This study will be presented at the IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (IEEE BMSB) on June 7, 2017.

Unlike ATSC 1.0, the ATSC 3.0 standard will provide the ability to send simultaneous Physical Layer Pipes (PLPs) at a variety of signal robustness levels, having the potential to greatly improve broadcast signal reception. Therefore, ATSC 3.0 is expected to be used to deliver service targeted to mobile receivers as well as service to fixed rooftop antennas over the same 6 MHz channel, likely using Scalable Hierarchical Video Coding (SHVC) to avoid redundancies in broadcasters' overall data stream, and Layered Division Multiplexing (LDM) to maximize mobile coverage. In this regard, a robust PLP optimized for mobile reception —and/or television receivers without outdoor antennas— in an area comparable to a TV station's ATSC 1.0 coverage will be readily receivable by rooftop antennas over a much larger area than today's 15 dB "DTV-equivalent" coverage contour.

In our study, we identify that all else equal, such a larger coverage area will give rise to increased overlap between same-network TV station affiliates. We calculate the extent of this increased overlap among affiliates of the four largest national broadcast

networks: ABC, CBS, NBC, and Fox. Conservatively, we estimate that as much as 75% of the population will have access to at least one redundant network affiliate, and 60% will have over-the-air access to two affiliates or more for all four major networks. As U.S. broadcasters rely increasingly on retransmission consent fees from Multichannel Video Program Distributors (MVPDs), we use a case study based on the Pittsburgh local TV market area to describe the retransmission consent negotiation issues that we believe may arise when multiple independently-owned affiliates of the same network overlap an MVPD's subscriber footprint.

Under proposed rules, a TV station should provide at least one ATSC 3.0 video stream that requires an SNR threshold equal or below the 15 dB level of the OET Bulletin No. 69. As explained in the NPRM, a station providing mobile video service requiring a minimum SNR below 15 dB would satisfy this requirement (see NPRM, p.48 *Preservation of Service*). Should ATSC 3.0 broadcasters transmit a signal intended for mobile receivers, the Commission will need to rethink its procedures for designating a TV station as *Significantly Viewed* in counties outside its DMA for purposes of determining the applicability of the Commission's non-duplication rules. Will mobile receivers be counted based on the address of their owners or based on the actual location of the receiver when tuned to a broadcaster?

The study included below is not meant to promote or discourage any particular future broadcast television business or service model. Rather, we hope to provide a reference to illustrate the potential issues that may arise in the ATSC 3.0 discussion and to promote the use of quantitative analysis to guide the policymaking process.

Quantifying LDM Mobile TV Service Coverage Spillover into Fixed Rooftop Reception: Increased Coverage Overlap Between U.S. Service Areas

Rolando Bettancourt* and Marvin A. Sirbu†
Department of Engineering and Public Policy*†, Tepper School of Business†
Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh PA 15213, USA
Email: {rbettancourt, sirbu}@cmu.edu

***Abstract*—ATSC 3.0 is likely to be used to deliver service targeted to mobile receivers as well as service to fixed rooftop antennas, likely using Scalable Hierarchical Video Coding (SHVC) to minimize total bitrate, and Layered Division Multiplexing (LDM) to maximize mobile coverage. A Physical Layer Pipe (PLP) with robust coding optimized for reception by mobile receivers in an area comparable to a TV station's ATSC 1.0 coverage will be readily receivable by rooftop antennas over a much larger area than today's 15 dB coverage contour. In the U.S., this larger coverage area will give rise to increased overlap between same-network TV station affiliates. We calculate the extent of increased overlap among affiliates of the four largest networks (ABC, CBS, NBC and Fox) over the population of the continental U.S. and conservatively estimate that as much as 75% of the population will have access to at least one redundant network affiliate, and 60% will have over-the-air access to two affiliates or more for all four major networks. U.S. broadcasters rely increasingly on retransmission consent fees from Multichannel Video Program Distributors (MVPDs). When multiple independently-owned affiliates of the same network overlap an MVPD's subscriber footprint, the MVPD can pit them against each other in bargaining over retransmission consent fees. We use a case study based on the Pittsburgh local TV market area to describe the retransmission consent negotiation issues that may arise and the regulatory framework that today conditions these negotiations.**

***Index Terms*—ATSC 3.0, Mobile TV, Retransmission Consent, Layered Division Multiplexing, LDM, Scalable Hierarchical Video Coding, SHVC, Coverage Overlap.**

I. Introduction

There have been numerous suggestions that ATSC 3.0 be used to provide service targeted to mobile receivers as part of a broadcaster's overall next-generation TV strategy [1]–[3]. A Physical Layer Pipe (PLP) with robust coding optimized for reception by mobile receivers in an area comparable to a TV station's ATSC 1.0 coverage will be readily receivable by rooftop antennas over a much larger area than this 15 dB coverage contour [4], [5]. Using these planning parameters in the United States (U.S.) will frequently result in new/additional coverage overlap between same-network TV station affiliates, with implications for program choice, carriage and retransmission consent with Multichannel Video Programming Distributors (MVPDs).

In the U.S., over-the-air broadcast TV is distributed across a complex structure of 210 *designated market areas* (DMA), which are groups of U.S. counties where people see roughly the same OTA TV options[1]. Within a DMA, a majority of local TV stations are affiliated with a national broadcast network —e.g. ABC, CBS, The CW, NBC, Fox [6]. For local TV affiliates of the same network, most of the popular programming comes from their parent network, and is thus the same[2]. Due to station ownership limitations [7], neighboring local TV affiliates typically don't share the same owners, and therefore they may compete where coverage already overlaps. In this paper, we conduct a propagation study to estimate the extent of additional coverage overlap that mobile TV can bring and consider the potential consequences.

One barrier to successfully deploying mobile TV has been the 20–30 dB of additional link budget required compared to fixed rooftop reception [5], [8]. To address this, ATSC 3.0 includes Layered Division Multiplexing (LDM) as part of its physical (PHY) layer, which is a more efficient RF channel multiplexing scheme than FDM/TDM when transmitting multiple program streams with dissimilar bitrates and robustness levels —e.g. fixed and mobile [4], [5]. Moreover, unlike ATSC 1.0, ATSC 3.0 provides the ability to send simultaneous PLPs at a variety of signal robustness levels defined via different modulation and coding schemes (MCS) [1], so broadcasters could, from the same broadcast tower, serve both fixed and mobile receivers [5]. In this regard, what seems to be the most cost-effective strategy for deploying mobile TV is to use LDM in conjunction with Scalable Hierarchical Video Coding (SHVC) [2], [9]. Here, a downscaled HD version to mobile receivers is proposed along with additional bits in a PLP targeted for rooftop receivers to realize a UHD version. In this way, fewer bits are required in total, and the redundancy of providing two complete program streams for both mobile

[1]DMA regions are the geographic areas in the U.S. in which local television viewing is measured by The Nielsen Company. For a detailed description, see http://www.nielsen.com/intl-campaigns/us/dma-maps.html.

[2]Because network affiliates usually serve different local metropolitan areas, however, they differ in the provision of tailored local news and other forms of local programming.

and fixed reception is avoided. However, as discussed, this can also create additional coverage overlap between TV stations' video streams.

In this paper, we quantify the extent of such an additional coverage overlap between major national broadcast network affiliates and we analyze its potential economic implications. First, we choose a representative ATSC 3.0 SHVC into LDM configuration and we assume that all TV stations in the U.S. will adopt it. Particularly, we assume TV stations maintain their assigned transmit power as proposed in [3]. Then, using the U.S. Federal Communications Commission (FCC) TVStudy interference analysis software [10] we calculate (a) today's existing coverage overlap with ATSC 1.0; and (b) the hypothetical coverage overlap that would result with ATSC 3.0's LDM, both in terms of area and population served. We focus on those local TV stations that are affiliated with the largest four U.S. national broadcast networks: ABC, CBS, NBC and Fox.

Secondly, we explore how overlapping coverage of same-network neighboring TV stations can affect a TV station's ability to extract retransmission consent fees in a given geographic area. In particular, we consider how an increase in same-network coverage overlap interacts with FCC rules regarding must-carry, retransmission consent, network non-duplication and distant signal importation. Our analysis makes use of the previously obtained ATSC 1.0 service coverage results, the current Nielsen's definition of existing DMAs and their associated counties, and the FCC list of *significantly viewed* (SV) TV stations [11].

The rest of the paper is structured as follows. Section II focuses on the technology and regulatory background of this paper. Section III describes data sources and methodology. Section IV defines the scenarios here considered and presents their resulting coverage. Section V discusses the potential economic implications of an additional coverage overlap. Section VI provides our conclusions.

II. Background

In this section we describe the most relevant aspects of (a) the use of SHVC and LDM to provide mobile TV service, and (b) the industrial structure of the U.S. TV industry, its relation to MVPDs, and the associated regulatory framework.

A. Mobile TV in ATSC 3.0 with SHVC and LDM

As noted above, a two-layer SHVC-into-LDM scheme has been proposed to facilitate the delivery of mobile TV services [2], [9]. At the source coding level, two SHVC layers are created from an original high-quality video source: a *base layer* (BL), optimized for mobile device displays, and an *enhancement layer* (EL), optimized for fixed rooftop reception and large-screen household TV sets. The BL corresponds to a downscaled lower-quality version of the original video source, while the EL, when received together with the BL, provides the incremental bits to bring the BL to the original video quality [9]. SHVC reduces the total bitrate requirement compared to simulcasting in two different qualities [12]. Examples of these scalable video qualities are resolution (e.g. HD to UHD), dynamic range (8-bit to 10-bit depth) and frame rate (e.g. 30 fps to 60 fps) [12].

At the transmission channel level, ATSC 3.0 incorporates the use of LDM for the simultaneous non-orthogonal transmission of the BL and EL with unequal error protection (UEP) [1]. The LDM *upper layer* (UL), which is intended for transmitting the BL, is encoded with a robust MCS so that mobile receivers can decode it at low SNR thresholds. The LDM *lower layer* (LL), which is intended for rooftop household reception, is encoded with a high-capacity MCS to take advantage of better reception conditions of rooftop antennas. It has been shown that the gain of LDM over time-division and frequency-division multiplexing (TDM/FDM) increases with the difference in the required SNR levels of the two layers [8], as indeed occurs with the simultaneous in-band provision of fixed and mobile services.

With the proposed ATSC 3.0 LDM transmitter, the output signal is the sum of the UL and LL OFDM carriers [5], [13]. The power levels at which both layers are added, P_{UL} and P_{LL}, is controlled by the so-called *injection level* (IL) ρ, which represent the difference (in dB) between the power allocated to the UL vs the LL, i.e. $\rho = 10\log_{10}(P_{\mathrm{UL}}/P_{\mathrm{LL}})$. Hence,

$$\begin{aligned} P_{\mathrm{UL}} &= \frac{1}{1+10^{\rho/10}} \cdot P_0 \\ P_{\mathrm{LL}} &= \frac{10^{\rho/10}}{1+10^{\rho/10}} \cdot P_0 \end{aligned} \tag{1}$$

where P_0 is the total (carrier) transmit power, i.e. $P_{\mathrm{UL}}+P_{\mathrm{LL}} = P_0$. In this way, mobile receivers see the LL as additional noise, while fixed receivers are able to perfectly decode and cancel the UL layer before decoding the LL due to the SNR differential [8]. Because of this, the LDM transmission scheme can be decomposed into two parallel channels with noise N_0B and SNR levels given by

$$\begin{aligned} \gamma_{\mathrm{UL}} &= \frac{P_{\mathrm{UL}}}{P_{\mathrm{LL}}+N_0B} \\ \gamma_{\mathrm{LL}} &= \frac{P_{\mathrm{LL}}}{N_0B} \end{aligned} \tag{2}$$

Similarly, taking γ_{UL} and γ_{LL} as the required minimum SNR for the MCS at the UL and LL respectively, the minimum carrier-to-noise ratio (CNR) planning levels required for the UL and LL streams to be decoded correctly are given by

$$\begin{aligned} \mathrm{CNR}_{\mathrm{UL}} &= \gamma_{\mathrm{UL}} + 10\log_{10}\left[1+10^{\rho/10}+10^{(\rho+\gamma_{\mathrm{UL}})/10}\right] \\ \mathrm{CNR}_{\mathrm{LL}} &= \gamma_{\mathrm{LL}} + 10\log_{10}\left[1+10^{-\rho/10}\right] \end{aligned} \tag{3}$$

Recent examples in the literature have shown that with their existing 6 MHz channel, ATSC 3.0 broadcasters using LDM can provide mobile service coverage fairly close to today's ATSC 1.0 15 dB coverage contour, and at the same time provide enhanced quality fixed services at that 15 dB level [4], [5]. However, it has also been noted that, because of its more robust coding, the LDM UL alone can be received by fixed rooftop receivers at distances far beyond today's 15 dB coverage contour [4], [5].

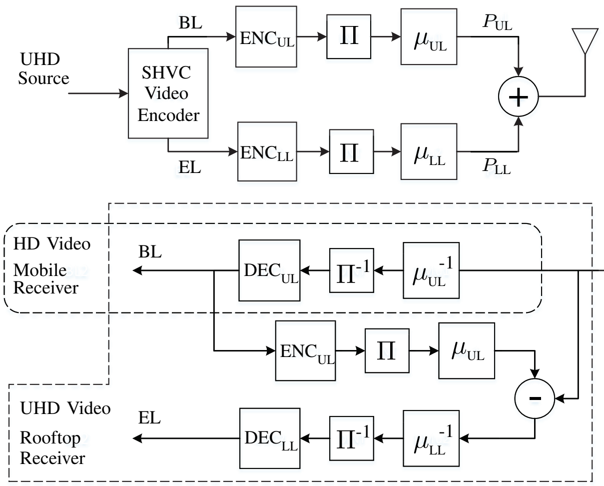


Figure 1. Source and channel coding of a SHVC over LDM video transmission, as shown in several ATSC 3.0 industry presentations. The BL and EL are encoded (ENC), passed though an interleaver Π and symbol-mapped $\mu\{\cdot\}$ at different SNR robustness levels. Then, they are combined at power levels P_{UL} and P_{LL}.

B. U.S. Over-the-Air TV Marketplace

By late April 2017 there were 2074 Full-Power or Class-A local television stations in the U.S., operating either in the Low-VHF, High-VHF or UHF bands. Among them, more than 80% are commercial television stations that are financed primarily via advertising [6]. Network affiliate TV stations bundle a limited amount of locally produced "local" programming, including news, weather, public affairs, etc., with network programming acquired from national broadcast networks with which they are affiliated (e.g. ABC, CBS, NBC, Fox)[3].

The amount of programming and its video quality that each TV station can broadcast and the population they can reach over the air is subject to (a) the existing broadcast technology (e.g. ATSC 1.0) and (b) FCC rules that limit the maximum transmit power and the maximum transmit antenna height of broadcast facilities[4]. With respect to the assignment of TV spectrum licenses, this has followed a first-come first-served approach, where a TV license can be granted in any place as long as there exists an available frequency —i.e. does not cause harmful interference to incumbent TV stations.

Although local TV stations provide their content to households directly through free over-the-air service, households can also receive local TV stations through retransmission by MVPDs such as cable, telco and satellite operators. As MVPDs compete with local TV stations for both viewers' attention and advertisers, the U.S. Congress mandates MVPD carriage as a way to ensure the economic viability of free OTA television. Local TV stations may elect MVPD carriage under either must-carry or retransmission consent [6]. Under must-carry, local TV stations can demand carriage of their primary program channel by MVPDs within their DMA, but without compensation from the MVPD. Alternatively, under retransmission consent, broadcast stations may demand some form of consideration in return for providing their consent to an MVPD to carry their signal[5].

To define who can demand MVPD carriage and where, the FCC uses DMAs as the basic geographic unit. Defined by Nielsen Media Research, each DMA is composed of a group of counties, generally clustered around a major metropolitan area, where local TV stations within the DMA hold statistical viewership dominance compared to TV stations of neighboring DMAs [6], [14]. Network affiliated TV stations often receive exclusive rights from the network to distribute its programming within their DMA, which gives them substantial leverage when negotiating retransmission consent fees. Moreover, the network non-duplication rule requires MVPDs to delete duplicating programming in a community that falls within a TV station's *protected zone*[6]. However, an exemption to this rule applies in the case of so-called *significantly viewed* (SV) out-of-DMA TV stations. SV stations are TV stations that have a significant OTA viewership outside of their DMA [11]. The determination of SV is made on a county by county basis [15]. SV stations cannot demand must-carry outside of their DMAs, but existing regulations do allow them to negotiate retransmission consent with any MVPD whose footprint falls within any portion of a county for which a TV station has been declared SV [16]. MVPDs are not required by the FCC to delete duplicate network programming when it comes from SV stations, and in-market network affiliates cannot prevent an MVPD from carrying them [17]. As noted, MVPDs have little incentive to negotiate retransmission consent with non-SV, out-of-DMA network affiliates as they would be required to delete any programming duplicative of the in-DMA affiliate.

In general, it is common to find mismatches between TV stations' coverage areas and their DMA areas. Some TV stations' coverage does not extend to their entire DMA, and/or their coverage area may spread across more than one DMA. Changing a TV stations' coverage area may affect how MVPDs whose footprint includes viewers of overlapping network affiliates determine which affiliate(s) to carry and how much to pay for the signal, or conversely, the ability of local broadcasters to extract retransmission consent payments.

III. Data Breakdown and Methodology

In this section we briefly summarize our data sources and revisit the FCC OET-69 methodology we use to calculate coverage and population served with TVStudy.

[3]TV stations may acquire other non-local programming, known as syndicated programming that can include game shows, reruns and, sometimes, some original programming. See [6].

[4]See 47 CFR §73.622(f) for DTV maximum power and antenna heights.

[5]Today, TV stations typically receive a fixed negotiated per-subscriber fee in exchange for their content, and virtually all commercial TV stations are able to extract positive revenue from MVPDs. Source: SNL Kagan, an offering of S&P Global Market Intelligence.

[6]See 47 CFR §76.92 Cable network non-duplication rules. In practice, networks and their affiliates have expanded the exclusivity zone to include entire DMAs.

A. Data Sources

The FCC Media Bureau's Consolidated Database System (CDBS) is a public access relational database that contains, among other information, the engineering data of each TV station in the U.S. This data is comprised of a TV station's transmitter geographic location, transmit power, frequency of operation, antenna height and the transmit antenna's horizontal and vertical patterns. Each broadcasting facility is indexed with a *facility ID*, which is in turn associated to the *call sign* of the TV station it belongs (e.g. KDKA-TV, WTAE, etc.). This information is used by TVStudy, in addition to topographic SRTM-3 data [18], to provide TV stations' coverage calculations over a 2 km by 2 km grid, which is delivered as a set of comma separated values (CSV) output files. We use MATLAB for further analysis of these files.

In today's 210 DMA regions, every county in the U.S. is in a DMA. We obtain the relationship between county and DMA data via S&P's SNL Kagan. This county by DMA report is updated annually, so we use the latest version which corresponds to the year 2016. In addition, we also use S&P's SNL Kagan to obtain for each DMA their complete list of TV stations and their corresponding network affiliations. To obtain each DMA's geographic boundary, we use MATLAB's mapping toolbox to perform the union operation of the polygons that represent each county. For each county, we use cartographic boundary shapefiles with a resolution of 500k = 1:500,000 obtained from the U.S. Census Bureau.

To obtain the data on TV stations' significantly viewed status, we use the official list of SV stations per county available from the FCC[7]. The SV list is a PDF file where TV stations are listed by state and by the county in which they are significantly viewed. This list was last modified in April 2016. To convert this information to a more manageable format, we use the extraction and data mining software SiMX TextConverter by taking advantage of the structure of the file.

B. TV Coverage Calculation Remarks

The FCC TVStudy software v2.2 implements the official FCC OET-69 directive for calculating coverage areas and population served for TV stations in the U.S. [19]. The OET-69 directive considers two different propagation models. A first model is a statistical path loss model akin to the ITU-P.1546 recommendation called the "FCC Curves", where path loss monotonically increases with respect to the distance to the transmitter. A second model, the irregular-terrain Longley-Rice (ITM) model, takes into account the terrain elevation characteristics [10], [19].

The protected service area of a TV station is defined by the so-called *noise-limited contour*, which is defined using the F(50, 90) curves —where reception is available for 50% of locations within the contour at least 90% of the time. The noise-limited contour bounds the area from the TV transmitter to the distance at which the field strength predicted by FCC curves falls to a minimum field, corresponding to today's ATSC 1.0 SNR level of 15 dB. To determine population served, the OET-69 method divides the area within this contour in 2 km by 2 km "cells" and uses the ITM model to determine the presence or absence of TV service in each cell.

To configure TVStudy's both contour and service (field strength) thresholds, we use the selected UL MCS SNR level to obtain the corresponding minimum CNR level using (3). Then, we adjust the co-channel and adjacent-channel interference protection ratios by the difference between today's 15 dB and the obtained CNR level.

To obtain the existing coverage overlap with ATSC 1.0, a simplified approach using only the noise-limited contours can be quite accurate. This is because existing frequency planning interference rules consider a very low interference level at the edge of coverage and quite below noise level, so TV stations' coverage areas are primarily noise-limited. However, as proposed by the Industry and in the FCC's NPRM [3], extending stations' coverage by selecting more robust MCS—keeping the same interference rules as of today—will lead to an interference-limited service area. In this regard, the amount of coverage shrinkage from the noise-limited case, due to interference, will depend on the density of broadcasters in the neighboring areas.

IV. Numerical Results

In this section we present our main results on predicted service coverage. First, we discuss the choice of bitrate and coverage for providing mobile TV service in the considered two-layer LDM transmission. Second, we show the distribution of number of viewable major network affiliates with both today's ATSC 1.0 and with the ATSC 3.0 LDM bitrate here considered. Finally, we focus on same-network coverage overlap results.

A. LDM Operating Scenario

As shown in (3), the coverage of each layer will be determined by the interplay between the minimum SNR of each layer's chosen MCS $\{\gamma_{\mathrm{UL}}, \gamma_{\mathrm{LL}}\}$ and the injection level ρ. Current LDM deployment studies have suggested values for ρ of 4 dB to 5 dB as a good trade-off between mobile coverage and LL bitrate at a coverage of 15 dB or less [4], [5], [13]. In [4], [5], it is also shown that the UL coverage for fixed rooftop receivers is much larger than for LL services at the 15 dB level.

In Table I we show three possible LDM UL service configurations depending on the bitrate required for the transmission of various bitrate program streams to mobile viewers. For each MCS, depending on the value of ρ, we show the resulting UL minimum CNR and the UL coverage for both handheld and rooftop reception. For rooftop reception we assume the existing OET-69 planning parameters [19]. For handheld reception, we assume an antenna gain of -7 dBi, a 10m to 1.5m 12 dB height loss, and a shadowing/fading margin of 3 dB [20]. Therefore, there is a 30 dB link budget difference between the two reception scenarios.

[7] At http://www.fcc.gov/mb/ in accordance with 47 U.S.C. §340(c)(2)

Table I
LDM UL Required CNR and Coverage for Typical Mobile HD Video Bitrate Configurations

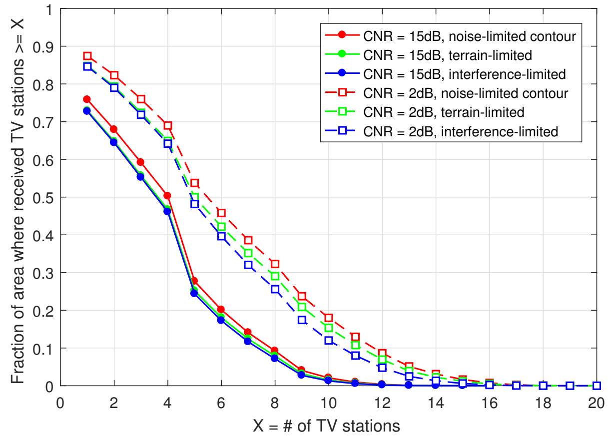
Bitrate	ρ = 5 dB			
	γ_{UL}	CNR	Coverage[1]	
			Mobile	Fixed
Low QPSK 3/15 2.0 Mbps	-4.3 dB	-2.6 dB	79 km	156 km
Medium QPSK 4/15 2.7 Mbps	-2.9 dB	-1.0 dB	76 km	150 km
High QPSK 6/15 4.1 Mbps	-0.5 dB	2.0 dB	72 km	138 km

[1] Coverage radius for a full-power TV station with transmit power equivalent to an omni-directional ATSC 1.0 coverage of 100 km.

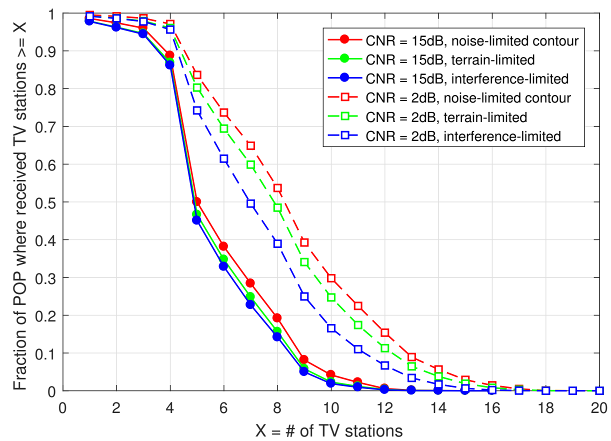
As Table I shows, there is a modest drop-off in coverage area as we move to higher bitrates for the mobile (UL) PLP. At 2.0 Mbps, the mobile program would be limited to 720p resolution; at 4.1 Mbps, a 1080p full HD program should be possible. With $\rho = 5$ dB, the LL can provide around 15 Mbps at the 15 dB contour [5], sufficient when added to the 4.1 Mbps of the LL to provide a 4K-UHD program via SHVC to a rooftop receiver. Increasing ρ to provide even more power to the UL increases the coverage into rooftop receivers only modestly but substantially decreases the LL bitrate, which would could constrain the quality of the enhanced program stream to less than 4K-UHD. We choose a conservative set of parameters for studying the potential coverage overlap by assuming the higher bitrate alternative for the mobile UL layer, (2 dB required CNR) and limiting the UL power allocation to $\rho = 5$ dB.

B. Impact on Number of Viewable Network Affiliates

In Fig. 2 we present the results obtained with TVStudy for (a) the existing ATSC 1.0 service, and (b) the hypothetical ATSC 3.0 UL coverage. Here we show a cumulative density function for the number of affiliates of the four largest national broadcast networks in the U.S., ABC, CBS, NBC and Fox, receivable by area (Fig. 2a), and by population (Fig. 2b). In each figure, we show the results obtained using noise-limited contours, the ITM terrain-and-noise-limited, and terrain-and-interference-limited results. We can see that for 15 dB coverage all three cases show a remarkably similar distribution. On the other hand, with 2 dB of required CNR, as discussed in III-B, we can clearly see the effect of interference on the enlarged coverage. Furthermore, Fig. 2b shows that over 85% of the population receives four local TV affiliates, which are presumably one each of the four networks, less than 50% receive 5 stations or more, and thus have at least one redundant affiliate. With our ATSC 3.0 scenario, more than 95% of the population will have access to four full power broadcasters, and affiliate overlap increases substantially, with at least 75% of the population having access to a redundant affiliate, albeit potentially at no more than HD-1080p quality[8].



(a) Fraction of U.S. area



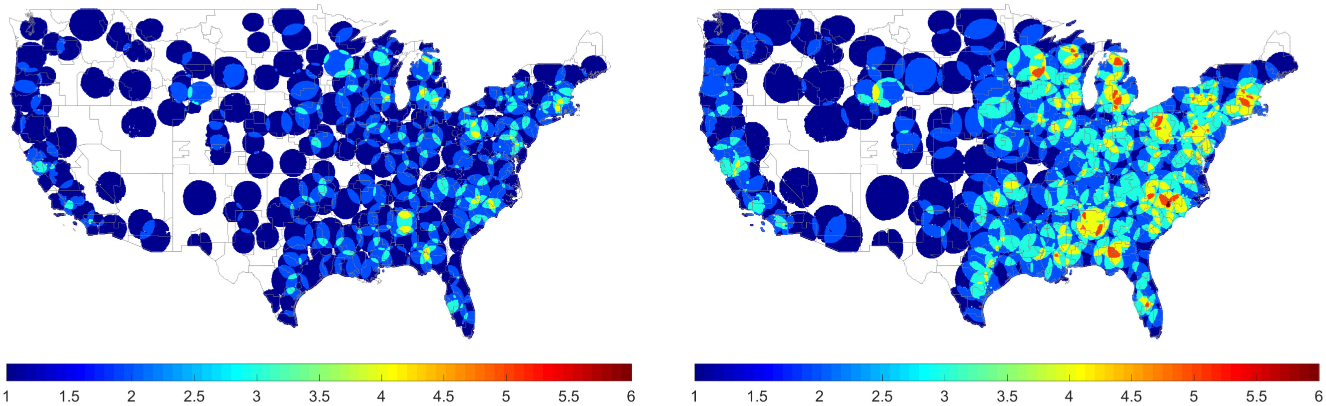
(b) Fraction of U.S. population

Figure 2. Complementary Cumulative Distribution Function (CCDF) of the number of affiliates available OTA across (a) the area and (b) the population of the Continental U.S., when considering the four largest national broadcast networks ABC, CBS, NBC and Fox.

C. Same-network Coverage Overlap

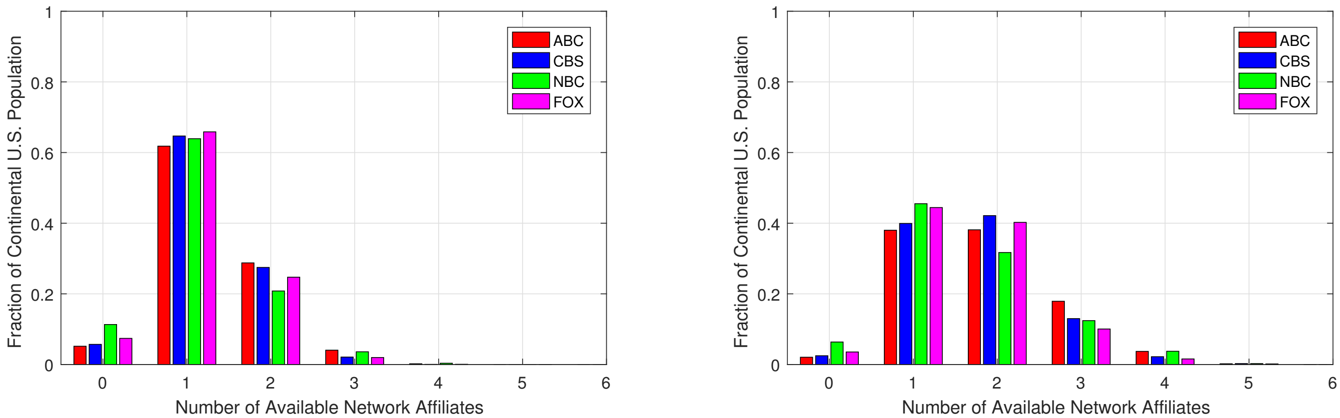
In Fig. 3 we show the geographic distribution of local TV affiliates of the ABC broadcast network. Here, Fig. 3a shows today's ATSC 1.0, while Fig. 3b shows our ATSC 3.0 scenario. We observe that even in today's ATSC 1.0 coverage the overlapping areas between affiliates is quite significant. We observe that the overlap between coverage areas is more prevalent in the eastern portion of the U.S. In the western part of the U.S. the population is much more scattered, so TV affiliates have greater geographic exclusivity. Although not shown here, in general we observe roughly the same pattern with the other three major networks —CBS, NBC and Fox.

[8] We have ignored here the role of LPTV and translators; actual network coverage today is larger than the coverage of Full-power and Class-A broadcasters alone. The need for translators in remote areas may be substantially reduced under this ATSC 3.0 scenario.



(a) CNR = 15 dB (b) CNR = 2 dB

Figure 3. Nationwide coverage of the ABC broadcast network for the two scenarios here considered.



(a) CNR = 15 dB (b) CNR = 2 dB

Figure 4. Distribution of the fraction of population with access to redundant local TV stations affiliates for each of the two scenarios and the national broadcast networks here considered.

In Fig. 4 we show for each broadcast network, the distribution of the number of different TV affiliates available across the U.S. population. For the ATSC 1.0 (15 dB) case, we see that 62–66% of the population is served by a single affiliate, 20–30% can choose between two, and a very small fraction has three or more choices. On the other hand, in the 2 dB case we observe that the fraction of the population with access to two affiliates grows to 35–40%, while 15–20% and $\tilde{5}$% would have access to three and four affiliates, respectively. In other words, a large majority of the population would have access to two or more affiliates of the same network, which may change the dynamics of retransmission consent negotiations.

V. Case Study: Potential Economic Implications

Negotiation between local network affiliates and MVPDs over what consideration is due the broadcaster in return for retransmission consent are increasingly contentious [21]. When TV broadcasters are the only source of popular network programming in the area, they have high negotiation leverage and can demand high retransmission consent payments. MVPD carriage disputes occur when the parties fail to reach to an agreement, and this can lead to temporary or permanent programming blackouts. In this regard, MVPDs have called on the FCC for permission to negotiate carriage with willing out-of-DMA stations in the event of a blackout [21].

To illustrate the potential economic implications of same-network TV stations enlarging their coverage areas, we present a case study considering the Pittsburgh DMA and its neighboring DMA of Wheeling-Steubenville (W-S). As of January 1st, 2017, the Pittsburgh DMA is the 23rd largest DMA in the U.S. with 1,160,220 TV homes, while W-S ranks 158th with 128,720 TV homes. In Fig. 5 we show the counties that form each DMA and the ATSC 1.0 coverage area of each DMA's local CBS network affiliate (KDKA-TV and WTRF-TV, respectively). We clearly observe that neither coverage area really matches with each DMA. In the case of KDKA-TV, it does not cover the entire Pittsburgh DMA, and also has substantial coverage overlap with counties in the neighboring Wheeling-Steubenville DMA. In the case of WTRF-TV, it covers its entire DMA and many areas beyond.

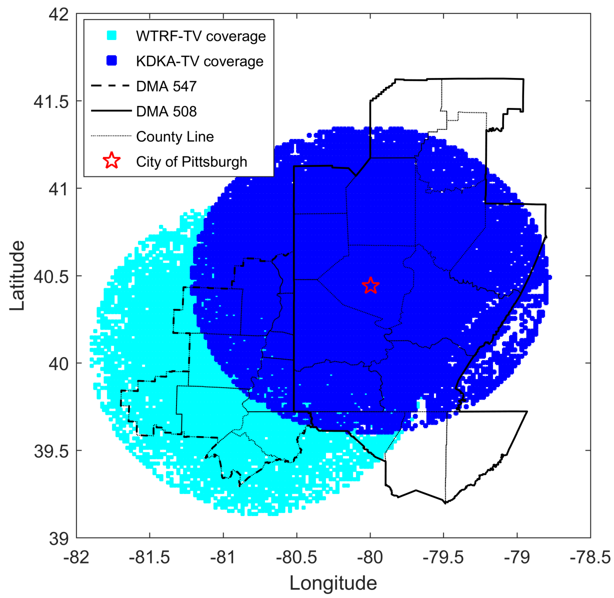


Figure 5. ATSC 1.0 coverage areas of the CBS network affiliates in DMA 508 (Pittsburgh) and DMA 547 (Wheeling-Steubenville).

As discussed in II-B, contractual agreements between networks and their affiliates, supported by FCC rules on distant signal importation, limit the ability of an MVPD to carry broadcast signals from a network affiliate outside the DMA in which the MVPD has its footprint. This is, in case of a dispute over retransmission consent fees with KDKA-TV, an MVPD in the Pittsburgh DMA cannot import the signal of the New York CBS affiliate or the Los Angeles CBS affiliate. However, an MVPD can reach an agreement with out-of-DMA CBS affiliates whose signal is deemed SV in counties where the MVPD has a presence.

Coverage overlap is a necessary, but not sufficient condition for a broadcaster to be SV in a county outside its DMA. Wheeling-Steubenville's WTRF-TV has significant OTA coverage in 10 of 16 counties of the Pittsburgh DMA, but according to the FCC, it is only SV in four of them: Greene PA, Washington PA, Monongalia WV, and Preston WV. On the other hand, Pittsburgh's KDKA-TV has significant coverage in 8 out of 11 of the Wheeling-Steubenville DMA counties, and it is SV in all of them. Factors other than coverage which influence SV status may include exclusive access to regional sports programming, or the quality of locally produced programming.

When, as a result of coverage overlap, a second affiliate of the same network becomes SV in an MVPD's service area, the MVPD now can threaten to carry network programming from the out-of-DMA TV station, if the latter is willing to accept a lower retransmission consent payment. The bargaining power of the in-DMA affiliate is substantially reduced as it loses its monopolistic bargaining position. Thus, if KDKA-TV demands too high retransmission consent fees from an MVPD serving, e.g., Washington County, that operator could decide to conclude a retransmission consent agreement with WTRF-TV at a more favorable rate as an alternative, and its subscribers would suffer no loss of CBS network programming. However, subscribers might still suffer if KDKA-TV has exclusive rights to important non-network programming such as Pittsburgh sports teams. Similarly, MVPDs within the Wheeling-Steubenville DMA, could choose to carry KDKA-TV in lieu of WTRF-TV.

In Fig. 6 we show the hypothetical case when KDKA-TV uses the proposed ATSC 3.0 SHVC-into-LDM configuration and thus substantially enlarges its coverage area. In this scenario, we see that KDKA-TV would have significant coverage in all of the counties in the Wheeling-Steubenville DMA. If OTA KDKA-TV viewers were sufficient for the station to be SV, then KDKA-TV could have the incentive to undercut WTRF-TV across its whole DMA. As of today, KDKA-TV is SV in all counties where it has some OTA coverage.

In general we observe that large market broadcasters are more likely to be classified as SV when they are receivable in adjacent smaller markets than vice versa[9]. While large market stations will thus have the greater opportunity to compete for retransmission consent revenues in smaller markets, they are also more likely to demand higher per subscriber fees. Conversely a small market broadcaster who is successful in becoming SV may have greater incentive to undercut the fees imposed by large market broadcasters because of the greater potential percentage increase in revenue.

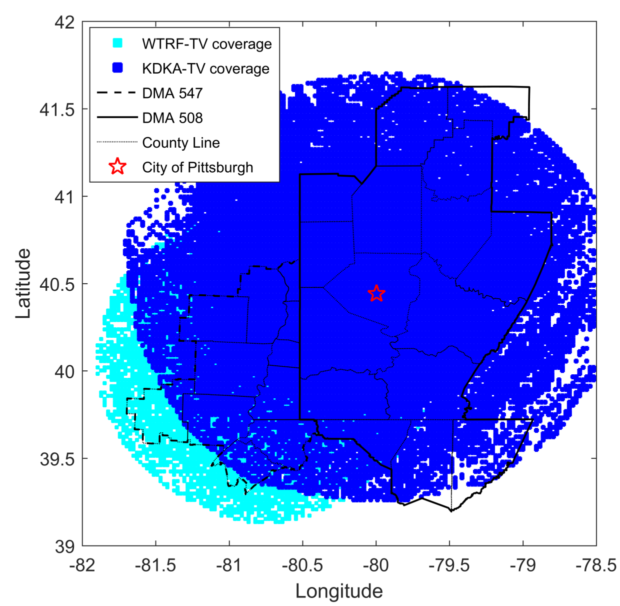


Figure 6. ATSC 3.0 LDM coverage area of the DMA 508 (Pittsburgh) CBS affiliate (KDKA-TV) vs. the ATSC 1.0 coverage area of the DMA 547 (Wheeling-Steubenville) CBS affiliate (WTRF-TV).

[9] We observed a similar pattern with the Youngstown, OH CBS affiliate (not shown here), which is located ˜120 km to the northwest of Pittsburgh PA.

VI. Conclusions

U.S. TV broadcasters moving to ATSC 3.0 and choosing to carry separate PLPs optimized for mobile and fixed receivers, will find that the mobile signal reaches fixed receivers over a much larger coverage area than today's ATSC 1.0 service. Increased coverage leads to increased overlap between affiliates of the same national network. Where today that overlap occurs for less than 40% of the population, in this study we conservatively estimate the extent of the increased competitive overlap and find that as much as 75% of the U.S. population will have access to at least one redundant major network affiliate, and that each major national broadcast networks would be providing, on average, two or more affiliates to approximately 60% of the population.

The ability of a network affiliated broadcaster to extract retransmission consent revenues from MVPDs which carry its signal rests in large part on its exclusive carriage of popular network programming within its market area. Increased overlap implies that MVPDs may have increased ability to pit affiliates against each other in these negotiations, without fear of losing access to network content, leading to reduced retransmission consent revenues for broadcasters.

Complex U.S. rules condition this negotiation on overlapping affiliates being *significantly viewed* outside their market area, a status based on measurements of over-the-air viewership of the overlapping affiliate by out-of-market households. Further research is required to understand what other factors besides OTA coverage may impact a TV station's SV status to better predict economic outcomes. At present, the FCC relies on third-party audience measurement companies for such data. When receivers may be mobile rather than fixed, new measurement standards will be required for determining when viewership is in- versus out-of-market, if the existing rules are not changed altogether [22]. However, parts of the current framework are prescribed by statute [17] and cannot be undone by the FCC on its own.

References

[1] L. Fay, L. Michael, D. Gmez-Barquero, N. Ammar, and M. W. Caldwell, "An Overview of the ATSC 3.0 Physical Layer Specification," *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 159–171, March 2016.

[2] R. Chernock, "ATSC 3.0 Overview [Keynote]," in *2015 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, June 2015.

[3] Joint Petition for Rulemaking: America's Public Television Stations, AWARN Alliance, Consumer Technology Association, National Association of Broadcasters, in the matter of Media Bureau Seeks Comment on Joint Petition for Rulemaking of America's Public Television Stations, the AWARN Alliance, the Consumer Technology Association, and the National Association of Broadcasters Seeking To Authorize Permissive Use of the "Next Generation TV" Broadcast Television Standard, GN Docket No. 16-142, April 13, 2016.

[4] L. Zhang, Y. Wu, W. Li, H. M. Kim, S. I. Park, P. Angueira, J. Montalban, and M. Velez, "Channel capacity distribution of Layer-Division-Multiplexing system for next generation digital broadcasting transmission," in *2014 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, June 2014, pp. 1–6.

[5] L. Zhang, W. Li, Y. Wu, X. Wang, S. I. Park, H. M. Kim, J. Y. Lee, P. Angueira, and J. Montalban, "Layered-Division-Multiplexing: Theory and Practice," *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 216–232, March 2016.

[6] Federal Communications Commission Report. In the Matter of Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming: Seventeenth Report, MB Docket No. 15-158, May 6, 2016.

[7] *47 C.F.R. § 73.3555(e)*.

[8] D. Gomez-Barquero and O. Simeone, "LDM Versus FDM/TDM for Unequal Error Protection in Terrestrial Broadcasting Systems: An Information-Theoretic View," *IEEE Transactions on Broadcasting*, vol. 61, no. 4, pp. 571–579, Dec 2015.

[9] C. Regueiro, J. Barrueco, J. Montalbn, U. Gil, I. Angulo, I. Eizmendi, P. Angueira, and M. Velez, "SHVC and LDM techniques for HD/UHD TV indoor reception," in *2015 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, June 2015, pp. 1–6.

[10] FCC, "TVStudy Interference Analysis Software [Online]," in *www.fcc.gov/engineering-technology/*, Mar. 2016.

[11] *47 C.F.R. 76.5(i)*.

[12] J. M. Boyce, Y. Ye, J. Chen, and A. K. Ramasubramonian, "Overview of SHVC: Scalable Extensions of the High Efficiency Video Coding Standard," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 26, no. 1, pp. 20–34, Jan 2016.

[13] S. I. Park, J. Y. Lee, S. Myoung, L. Zhang, Y. Wu, J. Montalbn, S. Kwon, B. M. Lim, P. Angueira, H. M. Kim, N. Hur, and J. Kim, "Low Complexity Layered Division Multiplexing for ATSC 3.0," *IEEE Transactions on Broadcasting*, vol. 62, no. 1, pp. 233–243, March 2016.

[14] Federal Communications Commission Report. In the Matter of Designated Market Areas: Report to Congress Pursuant to Section 109 of the STELA Reauthorization Act of 2014, MB Docket No. 15-43, June 3, 2016.

[15] *47 C.F.R. 76.54*.

[16] *47 C.F.R. § 76.92*.

[17] *47 U.S.C. 325 (b)*.

[18] NASA Jet Propulsion Lab, "Shuttle Radar Topographic Mission [Online]," in *https://www2.jpl.nasa.gov/srtm/*.

[19] FCC OET Bulletin No. 69: Longley-Rice Methodology for Evaluating TV Coverage and Interference, Feb. 06, 2004.

[20] European Broadcasting Unit - Tech. Report 3348, "Frequency and Network Planning Aspects of DVB-T2", Geneva, May 2013.

[21] FCC, "Implementation of Section 103 of the STELA Reauthorization Act of 2014, Totality of the Circumstances Test: Notice of Proposed Rulemaking," *Federal Register*, vol. 80, no. 191, pp. 59 706–59 719, October 2, 2015.

[22] ——, "Network Non-Duplication and Syndicated Exclusivity Rules: Further Notice of Proposed Rulemaking," *Federal Register*, vol. 79, no. 69, pp. 19 849–19 860, April 10, 2014.